Original Article

Phased-array Magnetic Resonance Imaging of the Prostate with Correlation to Radical Prostatectomy Specimens: Local Experience

Jin-Wei Kwek, Choon-Hua Thng,[1] Puay-Hoon Tan,[2] John Shyi-Peng Yuen,[3] James Boon-Kheng Khoo,[1] Swee-Tian Quek,[1] Juliana Teng-Swan Ho,[1] Kim-Ping Tan[4] and Christopher Wai-Sam Cheng,[3] Department of Diagnostic Radiology, Tan Tock Seng Hospital, [1]Department of Diagnostic Imaging, National Cancer Centre, and Departments of [2]Pathology, [3]Urology and [4]Diagnostic Radiology, Singapore General Hospital, Singapore.

PURPOSE: To evaluate local experience of phased-array magnetic resonance imaging (MRI) in the staging of locally advanced prostate carcinoma with comparison to clinical staging.

METHODS: The study population was 21 patients who underwent preoperative MRI with pelvic phased-array coils followed by radical prostatectomy. The MRI findings were correlated with completely embedded serially sliced and whole-mounted sections of the prostate gland and clinical staging.

RESULTS: Overall accuracy of 57.1% was obtained, with specificity of 90.0% and sensitivity of 27.3%. All but one case of locally advanced disease missed by MRI was microscopic. Clinical staging in these cases also achieved accuracy of 57.1%, specificity of 90.0% and sensitivity of 27.3%.

CONCLUSIONS: MRI with a phased-array coil has high specificity but low sensitivity for detection of extraprostatic disease. Phased-array MRI does not image microscopic tumour extension. It did not perform better than clinical staging and is not recommended for routine staging. [*Asian J Surg* 2004;27(3):219–24]

Introduction

Preoperative evaluation of clinically localized prostate cancer to select the best candidates for radical prostatectomy remains a challenge. This is because the presence of extracapsular disease is an important predictor of outcome after radical prostatectomy and may significantly influence biological and clinical recurrence.[1] Currently, a combination of serum prostate-specific antigen (PSA), clinical staging with digital rectal examination (DRE) and Gleason score is used to predict pathological stage of localized prostate cancer using Partin's table.[2] Staging by DRE and transrectal ultrasound (TRUS) is often of limited accuracy.[3] DRE has accuracies ranging from 44% to 82%, and TRUS from 58% to 86%.[4,5] Magnetic resonance imaging (MRI) of the prostate can potentially reveal local tumour extension. Current literature shows that MRI of the prostate is most suitable for patients with intermediate risk.[6] It can be performed with a phased-array coil, which is placed externally over the pelvis, or an endorectal coil. The phased-array coil is more commonly available than the endorectal coil. Husband et al have shown that phased-array coil MRI of the prostate yields superior image quality.[7] Other investigators, however, have shown that endorectal MRI is superior to phased-array MRI due to a better signal-to-noise ratio.[8,9] We describe our experience with phased-array MRI of the prostate, and evaluate its sensitivity, specificity and accuracy by correlating MRI results with whole-mount step-sectioned radical prostatectomy specimens.

Address correspondence and reprint requests to Dr. Jin-Wei Kwek, Department of Diagnostic Radiology, Tan Tock Seng Hospital, 11 Jalan Tan Tock Seng, Singapore 308433.
E-mail: Jin_Wei_Kwek@ttsh.com.sg • Date of acceptance: 9th May, 2003

Patients and methods

Patients and clinical staging

Between April 1999 and December 2001, we performed 40 radical prostatectomies in our centre. All patients had biopsy-proven prostate cancer before radical prostatectomy. Our study population consisted of 21 patients who underwent preoperative MRI before radical prostatectomy. None of the patients were deprived of surgery based on preoperative MRI findings. Except for one patient who delayed his operation for 89 days for social reasons, patients underwent radical prostatectomy within about 4 weeks of MRI. Patient mean age was 62.5 years (range, 50–74 years). Median serum PSA was 15.0 μg/L (range, 5.5–65.9 μg/L). The median Gleason score was 6.5 (range, 5–8) based on TRUS biopsy specimens (Table). Patients were assigned a clinical stage based on DRE findings.

Imaging studies

MRI examinations were performed using two 1.5T MRI systems (GE Signa LX, GE Medical Systems, Milwaukee, WI, USA; Siemens Magnetom Vision, Siemens Corporation, Erlangen, Germany). With pelvic phased-array coils in place, axial T1-weighted spin-echo (SE) images were obtained from the symphysis pubis to the aortic bifurcation with the following parameters: TR (repetition time) 600 msec, TE (echo time) 12 msec, 4 mm section thickness, 1 mm intersection gap, two signals averaged, 24 cm field of view (FOV), and matrix size of 320 × 356. This was followed by acquisition of transaxial and coronal T2-weighted fast SE images with the following parameters: TR 4,000 msec, TE 118–132 msec, 4 mm section with 1 mm intersection gap, 15–22 echo train, 2–4 signals averaged (NEX), 14–22 cm FOV, and a matrix size of 320 × 256, with right-to-left phase coding. An endorectal coil was not used.

Image analysis

Prior to surgery, all MR images were interpreted and reported by a single reader. The findings on these radiological reports were analysed to calculate the accuracy, sensitivity and specificity. Radiological-pathological correlation was performed in the presence of the radiologist and the pathologist after the radical prostatectomy specimens had been pathologically evaluated.

Table. Age, time between magnetic resonance imaging (MRI) and radical prostatectomy, serum prostate-specific antigen (PSA), biopsy Gleason score, preoperative (Preop) MRI findings, clinical stage (based on digital rectal examination) and pathological stage

Age (yr)	Time to operation (d)	PSA (μg/L)	Biopsy Gleason score	Preop MRI findings	Clinical stage	Pathological stage
66	14	16.3	5	Conf	T1c	T2aN0Mx
50	11	18.0	6	Conf	T1c	T2cN0Mx
63	12	6.5	6	Conf	T1c	T3aN0Mx
74	10	10.7	7	Conf	T2a	T3bN0Mx
69	10	15.2	7	Conf	T3	T2cN0Mx
61	89	19.0	6	Conf	T2a	T3aN0Mx
68	9	9.5	7	Conf	T2a	T3aN0Mx
62	3	13.5	7	Conf	T1b	T2cN0Mx
62	29	15.0	7	Bilateral SV	T1b	T2bN0Mx
62	1	24.8	8	Bilateral SV	T3	T3bN2Mx
67	10	7.1	5	Conf	T1c	T2bN0Mx
60	10	13.0	7	Conf	T1c	T3aN0Mx
64	29	6.5	5	Conf	T1c	T2cN0Mx
72	1	18.2	8	Conf	T1c	T3aN0Mx
62	7	65.9	7	Conf	T1c	T3aN0Mx
61	10	74.3	6	Conf	T2a	T2aN0Mx
61	8	18.1	7	Left NVB	T3	T3aN0Mx
59	10	46.9	7	Conf	T3	T3bN0Mx
65	7	10.1	6	Conf	T1c	T2bN0Mx
54	14	5.5	7	Conf	T1c	T2aN0Mx
51	19	12.8	6	Right SV	T2a	T3bN0Mx

Conf = radiologically confined to gland, no evidence of local extension; SV = radiological seminal vesicle extension; NVB = radiological neurovascular bundle involvement.

We adapted our criteria for MR image analysis from Hricak et al's study.[8] Criteria for extracapsular and neurovascular bundle extension included localized bulge with irregular margin; angular bulge at the posterolateral margin of the gland; asymmetry of the neurovascular bundle; and breach of the capsule with direct tumour extension. Criteria for invasion of the seminal vesicle included demonstration of low-signal-intensity tumour extension from the base of the gland into and around the seminal vesicles that resulted in low signal intensity of the involved seminal vesicles and obliteration of the angle between the prostate and the seminal vesicle; tumour extension along the ejaculatory ducts that resulted in the non-visualization of the ducts, decreased signal intensity of the seminal vesicles and loss of the seminal vesicle wall on the T2-weighted images; and isolated foci (skip metastases) of low signal intensity in the seminal vesicles on T2-weighted images.

Histological evaluation

The prostate gland was fixed in 10% buffered formaldehyde after surgical resection. It was then axially sectioned at approximately 5 mm intervals in a plane perpendicular to the long axis (base to apex) of the gland. The anterior, posterior, right lateral and left lateral margins were coated with different coloured ink, and the gland was completely embedded for histological examination. Microscopic examination determined the Gleason's grades and score, tumour extent, extracapsular penetration, and seminal vesicle and surgical margin involvement. Extracapsular extension was defined as full-thickness capsular penetration with cancer extension into the periprostatic soft tissue.[1] Invasion into but not through the capsule was categorized as organ-confined disease.[1] Seminal vesicle invasion was defined as invasion into or through the muscular wall of the seminal vesicle.[10]

Sensitivity, specificity and accuracy

To calculate the sensitivity, specificity and accuracy of MRI, true positive was defined as imaging diagnosis of local extension confirmed by radiological-pathological correlation. To calculate the sensitivity, specificity and accuracy of clinical staging, true positive was defined as DRE findings of local extension confirmed by pathology.

Results

Surgical pathological findings

Pathological staging according to the TNM system demonstrated T2a in three patients, T2b in three, T2c in four, T3a in seven and T3b in four.[11] Two dissected obturator lymph nodes were positive for malignancy in one patient, but these lymph nodes were less than 1 cm in size.

MRI findings

We correctly staged nine cases of organ-confined disease, one case with neurovascular involvement (Figure 1) and two cases with seminal vesicle involvement (Figure 2). One case of organ-confined disease was falsely reported as having bilateral seminal vesicle involvement.

Six cases of microscopic capsular invasion and one case of microscopic seminal vesicle involvement were missed. Both the pathologist and radiologist agreed that the degree of invasion was beyond imaging resolution in these cases. Another case with right seminal vesicle and neurovascular bundle involvement was reported as organ-confined disease. Review of the MR images of this case showed an isolated focus of low signal intensity in the right seminal vesicle that was identified retrospectively during the radiological-pathological correlation (Figure 3).

In the case with metastases to two obturator lymph nodes, the involved lymph nodes were less than 1 cm in short axis diameter on MRI and were reported as not enlarged. Actual surgical specimens of the involved lymph nodes were also less than 1 cm in size.

Overall, we achieved a low sensitivity of 27.3% (95% confidence interval, 95% CI, 9.7%, 56.6%), a high specificity of 90.0% (95% CI, 59.6%, 98.2%) and a moderate accuracy of 57.1%. The positive and negative predictive values were 75.0% and 52.9%, respectively.

Clinical staging findings

Nine cases of organ-confined disease and three cases of locally advanced disease were correctly staged. One case of organ-confined disease was overstaged and eight cases of locally advanced disease were understaged. Overall, the results were identical to MR staging, with sensitivity of 27.3%, specificity of 90.0% and accuracy of 57.1%. The positive and negative predictive values were 75.0% and 52.9%.

Discussion

MRI with and without endorectal coils has been investigated with a view to improving the accuracy of local staging of prostate cancer, but, thus far, is not recommended for routine local staging of prostate cancer.[12] Endorectal MRI is generally considered superior to phased-array MRI in the assessment of

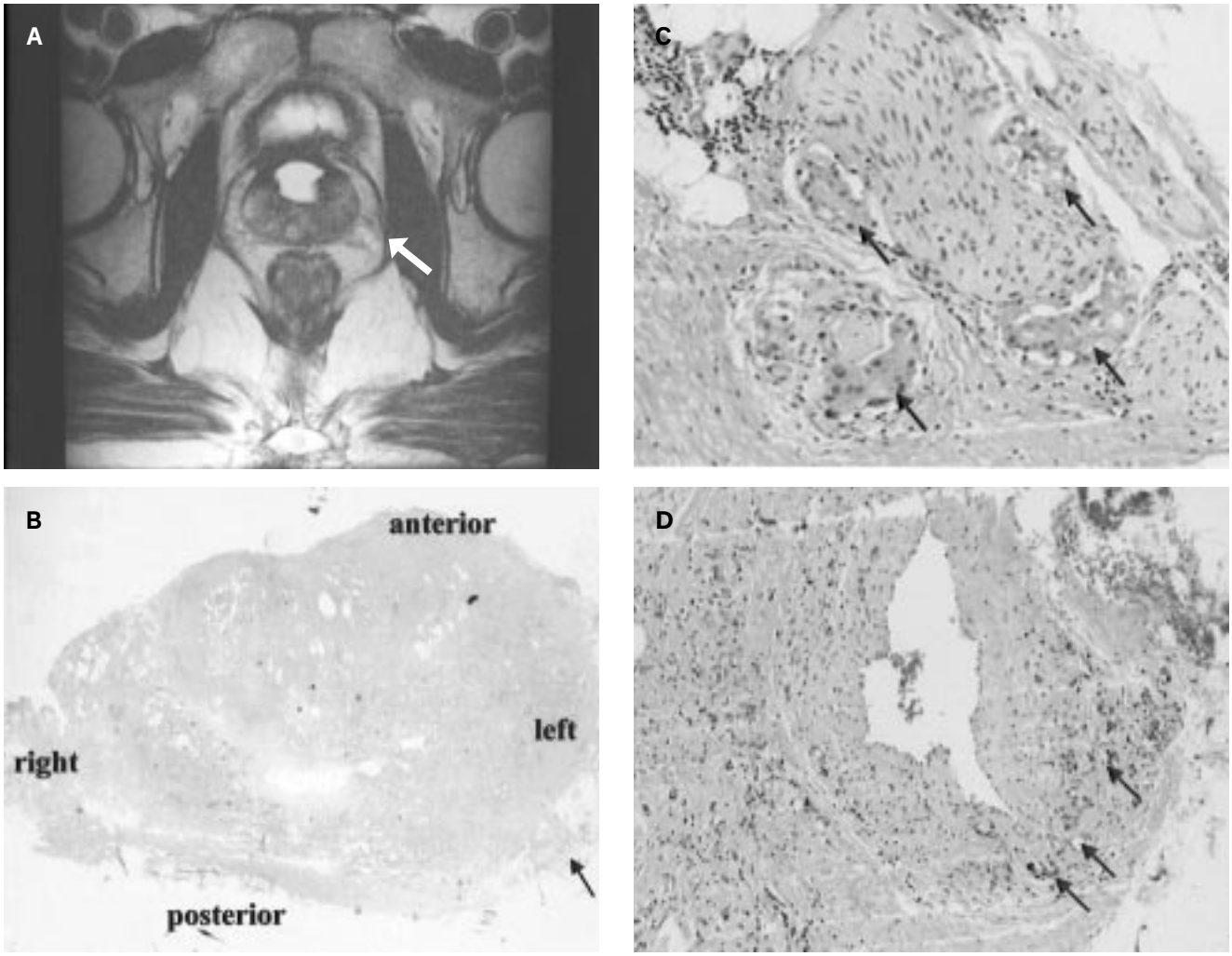

Figure 1. Stage pT3a carcinoma of the prostate gland. A) Pelvic phased-array axial T2-weighted image demonstrates a thickened left neurovascular bundle (arrow). B) Corresponding step section of the whole-mount prostatectomy specimen shows invasion by malignant acini around the left neurovascular bundle (arrow). C) Light microscopy confirms the presence of perineural invasion, and D) invasion into the wall of the blood vessel (malignant acini are indicated by arrows). Haematoxylin & eosin, original magnification × 200.

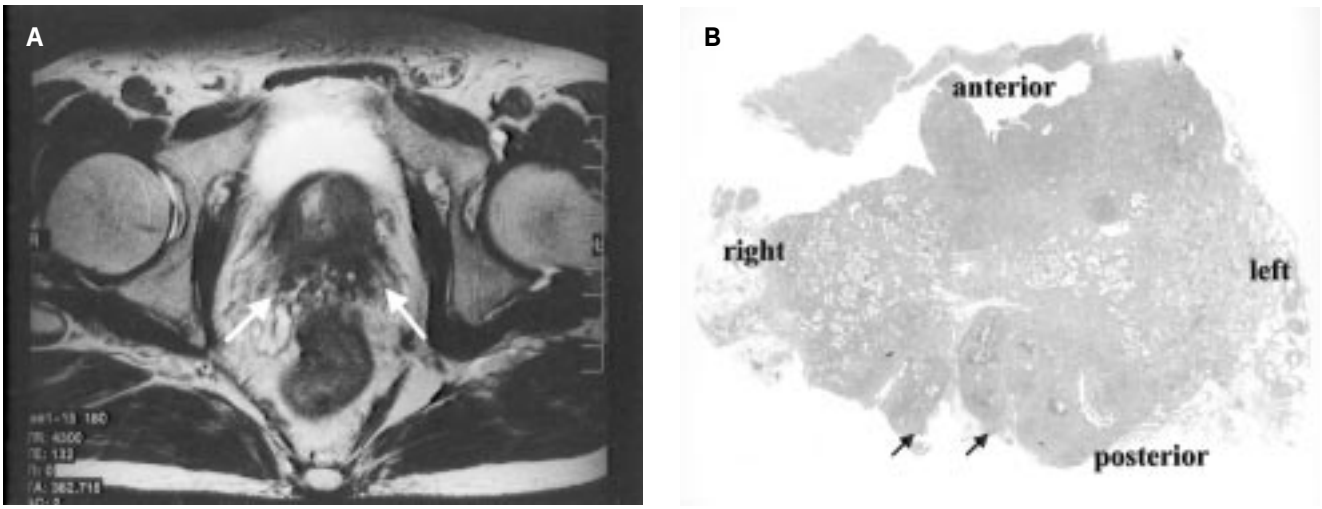

Figure 2. Stage pT3c carcinoma of the prostate gland. A) Pelvic phased-array axial T2-weighted image shows direct contiguous extension of tumour with low signal into and around both seminal vesicles (arrows), indicating bilateral seminal vesicle involvement. B) Corresponding step section of the whole-mount prostatectomy specimen shows malignant acini invading both seminal vesicles (arrows).

local extension.[8,9] This is due to a higher signal-to-noise ratio with the coil in the rectum closer to the prostate. The reported sensitivity and specificity of the endorectal coil for detection of locally advanced disease is 13% to 89% and 67% to 97%.[8,9,13–15] Although Ikonen et al achieved a very high specificity of 97% with an endorectal coil at the expense of a low sensitivity of 13% for the diagnosis of locally advanced prostate carcinoma,[16] most other studies using an endorectal coil show higher sensitivity than with a pelvic phased-array coil alone.

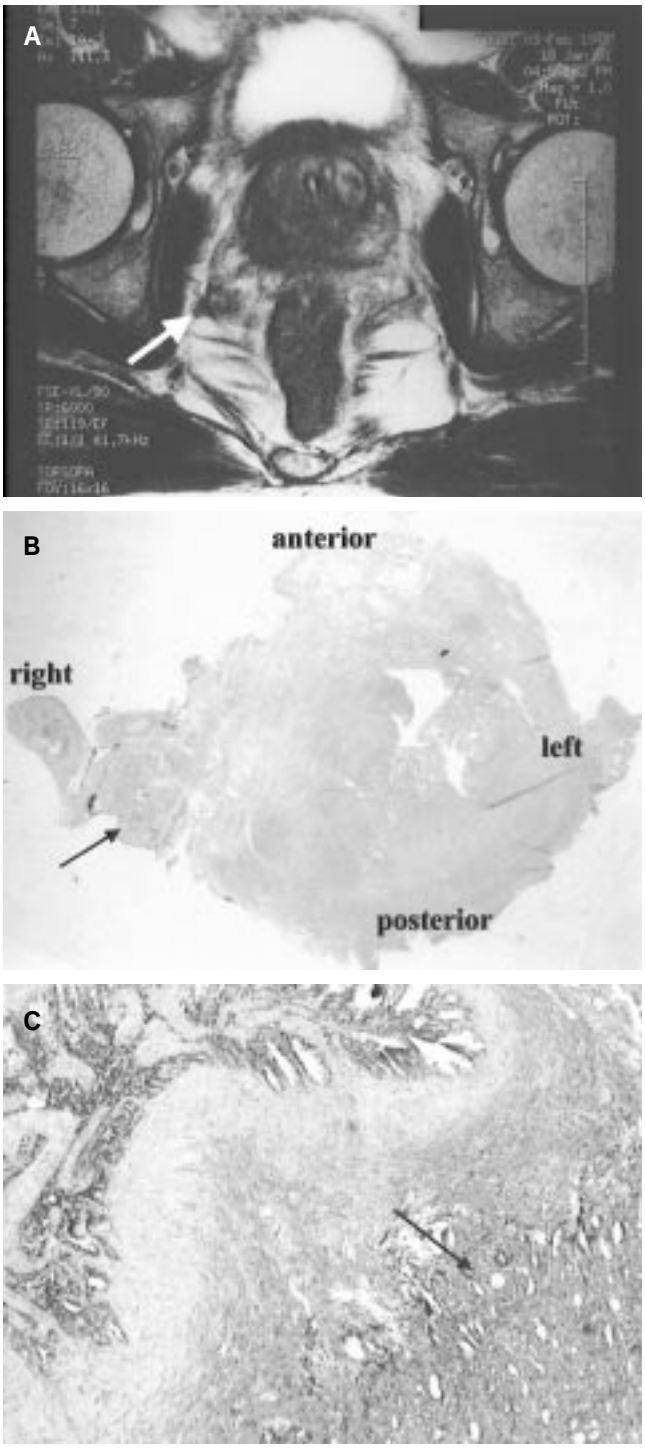

Figure 3. Stage pT3c carcinoma of the prostate gland. A) Pelvic phased-array axial T2-weighted image shows the low-signal tumour (T) in the right lobe of the prostate gland. The skipped focus of low signal in the right seminal vesicle was missed initially (arrow). B) The corresponding whole-mount step-section specimen shows invasion by malignant acini (arrow) into the right seminal vesicle. C) Light microscopy shows the malignant acini (arrow) invading the muscular wall of the right seminal vesicle. Haematoxylin & eosin, original magnification × 40.

The reported performance of phased-array MRI of the prostate to detect locally advanced carcinoma of the prostate is modest, with sensitivities of 33% to 74%, and specificities of 67% to 93%.[8,9,17] However, the phased-array coil is more readily available in clinical practice and does not have the discomfort of endorectal coil insertion. Husband et al have shown that image quality from phased-array coils can be superior to endorectal coils.[7]

Our study shows similar high specificity (90.0%), low sensitivity (27.3%) and moderate accuracy (57.1%) to Hricak et al's study with a phased-array coil.[8] Overall, phased-array MRI performed poorly, with similar results to clinical staging.

In our study, strict objective criteria adopted for the diagnosis of locally advanced disease ensured that a high specificity was achieved with the pelvic phased-array coil. This ensured that patients were not overstaged and deprived of potentially curative surgery. However, our sensitivity was low. In our pathological correlation, in all but one case of missed tumour extension, extension was microscopic. Therefore, phased-array MRI can detect macroscopic extension, but clinicians and radiologists should be aware of the low sensitivity achieved with this modality and the difficulties in detecting microscopic local extension.

D'Amico et al have shown that MRI may play a complementary role in the clinical staging of adenocarcinoma of the prostate[6] and is most useful in patients with intermediate risks based on Partin's nomogram (Gleason score of 6–7 and serum PSA of 10–20 ng/mL). Endorectal MRI in this group of patients is an independent predictor of 5-year PSA failure.[6] MRI in these patients can aid in patient selection for surgery and improved surgical outcome.

Endorectal coils, which our centre has recently acquired after completion of this study, may improve our sensitivity while maintaining the high specificity. Further reader experience may also improve our result.[8]

Conclusion

Phased-array MRI of the prostate performed poorly, giving similar results to clinical staging. It has a low sensitivity and

high specificity for the detection of local tumour extension in carcinoma of the prostate. Although phased-array coils are more readily available in imaging facilities, they are not recommended for routine staging as microscopic extension is difficult to detect.

Acknowledgements

This study was supported in part by a grant (No. 0537/2001) from the National Medical Research Council, Singapore. The authors would like to thank Ms. Wong Ee Hwee, Division of Clinical Trials and Epidemiological Sciences, National Cancer Centre, Singapore, for her help in reviewing the manuscript.

References

1. Epstein JI, Carmichael MJ, Pizov G, et al. Influence of capsular penetration on progression following radical prostatectomy: a study of 196 cases with long-term follow-up. *J Urol* 1993;150:135–41.
2. Partin AW, Kattan MW, Subong MS, et al. Combination of prostate-specific antigen, clinical staging and Gleason score to predict pathological stage of localized prostate cancer: a multivariate institutional update. *JAMA* 1999;277:1445–51.
3. McSherry SA, Levy F, Schiebler ML, et al. Preoperative prediction of pathological tumor volume and stage in clinically localized prostate cancer: comparison of digital rectal examination, transrectal ultrasonography and magnetic resonance imaging. *J Urol* 1991;146:85–9.
4. Ravery V, Boccon-Gibod L. T3 prostate cancer: how reliable is clinical staging? *Semin Urol Oncol* 1997;15:202–6.
5. Yu KK, Hricak H. Imaging prostate cancer. *Radiol Clin North Am* 2000;38:59–85.
6. D'Amico AV, Whittington R, Malkowicz JB, et al. Endorectal coil magnetic resonance imaging as a predictor of biochemical outcome after radical prostatectomy in men with clinically localized disease. *J Urol* 2000;164:759–63.
7. Husband JE, Padhani AR, MacVicar AD, et al. Magnetic resonance imaging of prostate cancer: comparison of image quality using endorectal and pelvic phased array coils. *Clin Radiol* 1998;53:673–81.
8. Hricak H, White S, Vigneron D, et al. Carcinoma of the prostate gland: MR imaging with pelvic phased-array coils versus integrated endorectal-pelvic phased-array coils. *Radiology* 1994;193:703–9.
9. Yu KK, Hricak H, Alagappan R, et al. Detection of extracapsular extension of prostate carcinoma with endorectal and phased-array coil MR imaging: multivariate feature analysis. *Radiology* 1997;202: 697–702.
10. Ohori M, Scardino PT, Lapin SL, et al. The mechanisms and prognostic significance of seminal vesicle involvement by prostate cancer. *Am J Surg Pathol* 1993:17:1252–61.
11. Spiessl B, International Union against Cancer. *TNM Atlas: Illustrated Guide to the TNM/pTNM Classification of Malignant Tumours*, 3rd edition, 2nd revision. Berlin, New York: Springer-Verlag, 1992.
12. Amis ES Jr, Bigongiari LR, Bluth EI, et al. Pretreatment staging of clinically localized prostate cancer. American College of Radiology. ACR Appropriateness Criteria. *Radiology* 2000;215(Suppl): 703–8.
13. Bartolozzi C, Menchi J, Lencioni R, et al. Local staging of prostate carcinoma with endorectal coil MRI: correlation with whole mount radical prostatectomy specimens. *Eur Radiol* 1996;6:339–45.
14. Huch Boni RA, Boner JA, Debatin JF, et al. Optimization of prostate carcinoma staging; comparison of imaging and clinical methods. *Clin Radiol* 1995;50:593–600.
15. Schnall MD, Imai Y, Tomaszewski J, et al. Prostate cancer: local staging with endorectal surface coil MR imaging. *Radiology* 1991; 178:797–802.
16. Ikonen S, Karkkainen P, Kivisaari L, et al. Magnetic resonance imaging of clinically localized prostatic cancer. *J Urol* 1998;159: 915–9.
17. Kier R, Wain S, Troiano R. Fast spin-echo MR images of the pelvis obtained with a phased-array coil; value in localizing and staging prostatic carcinoma. *AJR Am J Roentgenol* 1993;161:601–6.